PATENT ABSTRACTS OF JAPAN

(11)Publication number : **2000-249688**

(43)Date of publication of application : **14.09.2000**

(51)Int.Cl. G01N 27/84
G01N 21/91

(21)Application number : **11-053277**

(22)Date of filing : **01.03.1999**

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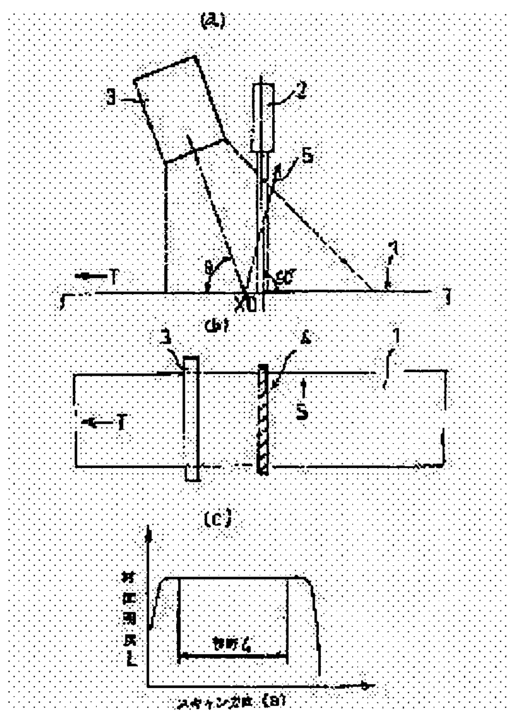
(54) WET FLUORESCENT MAGNETIC PARTICLE INSPECTION METHOD



(57)Abstract:

PROBLEM TO BE SOLVED: To improve an inspection accuracy without requiring shading correction by facilitating shifting a specular reflection light by a light source out of a camera visual field, thereby reducing an illuminance irregularity of a surface of a material to be inspected and raising an illuminance within the camera visual field.

SOLUTION: A magnetic particle solution is adhered to a surface of a material 1 to be inspected while the material being transferred is magnetized. Magnetic particles aggregating to a leaking magnetic flux part generated to a defect part emit light because of an illuminating light source 2. Data of images picked up by a line sensor camera 3 is processed, thereby detecting the result of the surface of the material 1 according to this wet fluorescent magnetic particle inspection method. The camera 3 is arranged so that a scan direction S becomes orthogonal to a transfer direction T for the material 1 and perpendicular to the surface of the material 1. The light source 2 is set in parallel to the camera scanning direction S and inclined by an angle θ to the surface of the material 1 whereby a specular reflection light 5 is prevented from entering a light- receiving face of the camera 3.

LEGAL STATUS

[Date of request for examination]

[Date of sending the examiner's decision of rejection]

[Kind of final disposal of application other than the examiner's decision of rejection or application converted registration]

[Date of final disposal for application]

[Patent number]

[Date of registration]

[Number of appeal against examiner's decision of rejection]

[Date of requesting appeal against examiner's decision of rejection]

[Date of extinction of right]

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2.**** shows the word which can not be translated.
3.In the drawings, any words are not translated.

DETAILED DESCRIPTION

[Detailed Description of the Invention]
[0001]
[The technical field to which invention belongs] This invention makes magnetic powder liquid adhere to the front face, irradiates the point, magnetizing inspected material, for example, steel, and relates to the wet fluorescent-magnetic-powder crack detection which detects surface discontinuity by taking a photograph with a camera and analyzing image data.
[0002]
[Description of the Prior Art] Generally, automatic wet fluorescent-magnetic-powder crack detection is adopted by making surface discontinuity (a crack, crack, etc.) of steel into the detection method. This crack detection is a method of sprinkling magnetic powder liquid with the spraying means 13, magnetizing the inspected steel 11 under conveyance with the magnetization coil 12 as shown in drawing 5 , irradiating the fluorescent magnetic powder condensed in the magnetic-leakage-flux section generated in said steel 11 surface-discontinuity section according to the ultraviolet-rays light source 14, making it emitting light, taking a photograph with CCD camera 15, a television camera, etc., and an image processing system 16 performing various analysis processings based on that image data, and detecting surface discontinuity.
[0003] However, since the area sensor (two-dimensional CCD) is adopted as said CCD camera 15 (refer to drawing 6) by this method as shown in drawing 7 (a) As shown in drawing 7 (b), it mainly originates in a photography image (visual field 17) light source 14 itself (as the illuminance nonuniformity 19 by the strong regular-reflection light 18 arises and it is shown in this drawing 7 (c), the portion 20 to which the brightness of steel natural complexion, i.e., a front face, becomes strong is made, and this serves as defective incorrect detection.). In wet fluorescent-magnetic-powder flaw detection, since the front face of inspected steel 11 has got wet with water, as shown in drawing 8 , the strong regular-reflection light 18 of the light source 14 exists.
[0004] Conventionally, in order to amend the above-mentioned illuminance nonuniformity 19, processing called a shading compensation in an image processing is performed.
[0005]
[Problem(s) to be Solved by the Invention] Then, on the occasion of the flaw detection of inspected steel 11 front face, how to adjust the angle of a camera 15 and the light source 14 as a method of making it said regular-reflection light 18 not go into the light-receiving side of a camera 15 can be considered. Usually, although the light source 14 will be aslant arranged as shown in drawing 7 (a) in order to install a camera 15 at right angles to inspected steel 11 front face so that the optical scale factor may become fixed In order to make it the regular-reflection light 18 not go into the camera visual field 17 When it is necessary to lean the light source 14 more than constant value as shown in drawing 9 (a), and the area sensor camera 15 is adopted, as shown in drawing 9 (b) There is a problem of the nonuniformity of the illuminance within the visual field 17 of the area sensor camera 15 (brightness on the front face of steel) becoming large, and a shading compensation being needed, or the part where an illuminance becomes low too much by theta whenever [tilt-angle / of the light source 14] occurring, and the amount of

defective part not shining, and becoming detection impossible.
[0006] This invention is to offer the wet fluorescent-magnetic-powder crack detection which can aim at improvement in inspection precision, without having been made in view of the above troubles, and being able to make regular-reflection light by the light source easy to remove from a camera visual field, and the place made into the object being able to make small illuminance nonuniformity on the front face of inspected material, and being able to raise the illuminance within a camera visual field, and requiring a shading compensation.
[0007]
[Means for Solving the Problem] In this invention, in order to attain the above-mentioned object, the following technical means are provided. Namely, while this invention magnetizes inspected material under conveyance, magnetic powder liquid is made to adhere to the front face. By making magnetic powder condensed in the magnetic-leakage-flux section generated in the inspected material surface-discontinuity section according to the exposure light source emit light, and processing image data photoed with a line sensor camera Are the wet fluorescent-magnetic-powder crack detection which detects a defect on a front face of inspected material, and said line sensor camera is arranged so that it may become vertical to an inspected material front face, while the inspected material conveyance direction and the scanning direction cross at right angles. The feature is in a point of making said light source inclining at an angle at which it is parallel to the scanning direction of said camera, and regular-reflection light does not enter in a light-receiving side of said camera to an inspected material front face.
[0008] In this case, a visual field of the inspected material conveyance direction (the direction of a normal of the scanning direction) which intersects perpendicularly with that scanning direction a line sensor camera Only by leaning the light source slightly, since it is far small as compared with an area sensor camera (refer to drawing 1 and drawing 6) The regular-reflection light can be easily removed from a line sensor visual field (refer to drawing 1). And illuminance nonuniformity by leaning the light source, since the visual field of the inspected material conveyance direction of said the camera is small is so small that it can be disregarded. And an illuminance can be raised, therefore a shading compensation of said inspected material conveyance direction is unnecessary, there is no defective incorrect detection, and flaw detection precision can be raised.
[0009] Moreover, this invention can make said light source the line light source longer than a visual field of the scanning direction of a line sensor camera, and can consider it as a configuration arranged to the scanning direction of said camera, and parallel. In according to this configuration being able to make small illuminance nonuniformity of the scanning direction of a line sensor camera and a shading compensation of the camera scan direction becoming unnecessary, an illuminance within a line sensor camera visual field can be raised substantially. Furthermore, wet fluorescent-magnetic-powder crack detection concerning this invention has the feature in a point illuminance distribution by the light source on a front face of inspected material is made to have the location which serves as max by the initial state in said light source side rather than a visual field location of a line sensor camera.
[0010] In addition, even if it changes distance with an inspected material front face, the light source, and a line sensor camera, brightness of an image within a camera visual field does not change a lot. On the other hand, illuminance distribution of the conveyance direction on a front face of inspected material by source of the slanting illumination light is the convex type distribution which has a peak of 1 (refer to drawing 2 (a)). Since according to the configuration of this invention a peak of an illuminance is in the same side as the light source to a line sensor camera visual field when inspected material displaces to the light source, change to which said illuminance peak location moves horizontally (the inspected material conveyance direction), and becomes bright, and change to which distance on the light source and a front face of inspected material becomes near negate each other, and brightness change as the whole is small. That is, it is possible for there to be no illuminance change, and for serious effect for defective detectability ability to seldom come out, but to be able to prevent defective incorrect detection, and to secure flaw detection precision with a variation rate of inspected material.
[0011] In addition, change which change a peak location of an illuminance moves horizontally when a peak of an illuminance is in a side further than the light source to a line sensor camera visual field, and it

is bright changeless, and distance become near, and becomes bright laps, it becomes as a whole more bright, a big illuminance change arises with a variation rate, and it becomes the cause of incorrect detection. Moreover, although there is no brightness change by a peak location of an illuminance moving horizontally when a peak of an illuminance is in agreement with a visual field of a line sensor camera, distance becomes near and it becomes bright, and it is bright as a whole, and a big illuminance change arises with a variation rate, and it becomes the cause of incorrect detection.

[0012]

[Embodiment of the Invention] Hereafter, 1 operation gestalt of this invention is explained based on a drawing. Drawing 1 - drawing 3 show the first operation gestalt of the wet fluorescent-magnetic-powder crack detection concerning this invention. In addition, this invention is the same as usual at the point of detecting the defect of inspected material 1 front face, by making magnetic powder liquid adhere to the front face, magnetizing the inspected material 1 under conveyance (steel), making the magnetic powder condensed in the magnetic-leakage-flux section generated in the inspected material 1 surface-discontinuity section according to the exposure light source 2 emit light, and processing the image data photoed with the camera 3 (refer to drawing 5).

[0013] With the first operation gestalt of this invention, the line sensor camera 3 is used as a camera. This camera 3 is arranged so that it may become vertical to inspected material 1 front face about it, while making the inspected material 1 conveyance direction T and the scanning direction S cross at right angles. The line light source is adopted as said light source 2, and moreover, the illuminance peak location X0 leans this to the angle theta (70 degrees) at which it is parallel to the scanning direction S of said camera 3, and the regular-reflection light 5 does not enter in a camera light-receiving side to inspected material 1 front face to a visual field 4 at a light source 2 side, and it arranges. In addition, as a slash shows the visual field 4 of the line sensor camera 3 to drawing 1 (b), it is band-like [long and slender to the cross direction of inspected material 1], and the visual field of the inspected material 1 conveyance direction T becomes very narrow as compared with an area sensor camera.

[0014] Moreover, the line light source (refer to drawing 1 (b)) longer enough than the visual field of the scanning direction S of the line sensor camera 3 is used for said line light source 2. Therefore, within the camera visual field 4, it is [no nonuniformity] almost and is fixed, and there is no need for a scanning direction S shading compensation as the brightness of the front face of inspected material 1, i.e., the **** illuminance of the scanning direction S, is shown in drawing 1 (c). In addition, since a camera visual field is narrow, and the exposure range of this direction T is narrow and ends, the illuminance nonuniformity of the inspected material 1 conveyance direction T is dramatically small, and can still raise the illuminance within the camera visual field 4.

[0015] Generally, the illuminance distribution L in inspected material 1 front face by the slanting light source 2 is the convex type distribution (criteria) which has one peak, as shown in drawing 2 (a). A peak location expresses this distribution by the system of coordinates used as X0=0, and sets it to L (x). As an illuminance is the function of the distance (r) of the light source 2 and inspected material 1 and it is shown in drawing 2 (b) in consideration of generally being in inverse proportion to the square (r2) of distance, considering the case where the peak location of an illuminance is in X0=X, according to an initial state, illuminance distribution [in this case] M (x) is shown by the degree type (1).

[0016]

[Equation 1] M(x) =L(x-X0)/(r/R)2 [0017] Next, since inspected material 1 is slanting lighting when only distance h considers the case where the light source 2 is approached as shown in drawing 2 (c), the peak location and distance of illuminance distribution change as follows, respectively.

[0018]

[Equation 2] X0 ->X0-h/tan theta [0019]

[Equation 3] R->r-h/sin theta [0020] For this reason, a formula 1 becomes like a degree type (several 4).

[0021]

[Equation 4] N (x) (r-h/sin theta) =L (x-X0+ h/tan theta)/2 [0022] When the visual field center of the line sensor camera 3 is X= 0, the illuminance change (namely, brightness change of an image) by this displacement h is expressed with a formula 5.

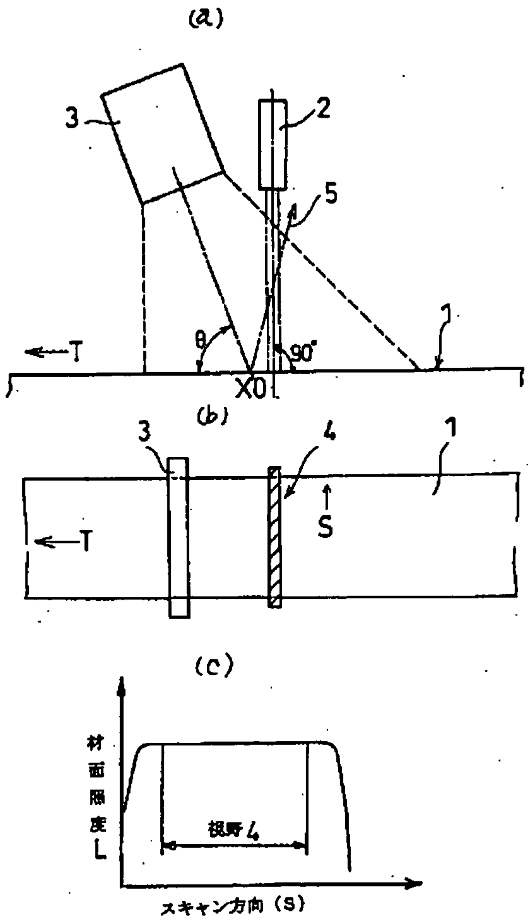
[0023]
[Equation 5] N (0) -M (0) **(h/tan theta) -L'(-X0) /(r/R) 2+2-(h/sin theta) -L(-X0)/{r (r/R) and 2} = {L'(-x0)/tan theta+2 and L (-x0) / (r-sin theta)}, h/(r-R) 2 [0024] here -- drawing 2 -- (-- c --) -- being shown -- as -- inspected material -- one -- change -- h -- having carried out -- the time -- effect -- X -- zero -- positive/negative -- a case -- having divided -- conditions -- (-- A --) -- (-- B --) -- (-- C --) -- ******** -- inquiring .
[0025] Conditions (A) X0> 0 (when an illuminance peak is in a far side from the light source 2 to the visual field center of the line sensor camera 3)
the brace of a formula 5 -- {-- } -- the 1st -- term >0 (**L' (x) is positive at X< 0), and the 2nd -- it is term >0. This means that change to which an illuminance peak location moves horizontally and becomes bright, and change to which distance r becomes near and becomes bright mean being added, and become as a whole more bright. Therefore, a big illuminance change will occur with displacement h.
[0026] Conditions (B) X0=0 (when an illuminance peak is in agreement with the visual field center of the line sensor camera 3)
the brace of a formula 5 -- {-- } -- inside -- 1st term =0= (**L' (x) is zero at X= 0), and the 2nd -- it is term >0. Although there is no change of the brightness by an illuminance peak location moving this horizontally, it means that distance becomes near and becomes bright, and means becoming bright as a whole. Therefore, a big illuminance change will occur with displacement h.
[0027] (Condition C) X0<0 (in the case of the first operation gestalt of this invention in the location from which the peak of an illuminance separated only x to the same side as the light source 2 to the visual field center of the line sensor camera 3 (refer to drawing 2 (b) and (c))) the brace of a formula 5 -- {-- } -- the 1st -- term >0 (**L' (x) is negative at X< 0), and the 2nd -- it is term >0. Change to which the illuminance peak location x moves this to the horizontal location xh, and it becomes bright, and change to which distance r becomes near and becomes bright mean negating each other, and it expresses that the brightness change as the whole is small. Therefore, illuminance change will not not much arise with the displacement h of inspected material 1. especially -- the inside of a formula 5 -- {} -- illuminance change can be thoroughly negated by choosing the location X0 where inside becomes zero, and an angle theta.
[0028] In addition, if illuminance change is several % - about 10%, since the serious effect for the detectability ability of a defect (crack) will not appear in a actual target, it is not necessary to make illuminance change into zero thoroughly on conditions (C), therefore even if conditions (C) are quite rough setting out, they can expect sufficient effect from him. And at the result of an experiment, when displacement h of inspected material 1 is set to 40mm, illuminance change whose about 50% was on conditions (A) is checking that it can decrease to about 5% by conditions (C) about 20% on conditions (b). As mentioned above, since according to the first operation gestalt the brightness of an image does not change a lot even if it changes distance with inspected material 1, the line light source 2, and the line sensor camera 3, it is not necessary to carry out a shading compensation. However, flaw detection precision is securable by amending the quantity of light itself for a slanting exposure.
[0029] Moreover, in the above-mentioned first operation gestalt, as a result of performing illumination photometry based on the image data photoed with the line sensor camera 3, as shown in drawing 3 (a) and (b), about 1 constant value is acquired and the **** illuminance in the conveyance direction T of inspected material 1 (location within the line sensor visual field 4) and the scanning direction S (location in inspected material width of face) is checking that a shading compensation is unnecessary. In addition, in this illumination photometry, in the conveyance direction T of inspected material 1, one scan (it is 1mm on ******) of the line sensor camera 3 is divided into five on an one inspected material center line, crosswise [of inspected material 1], the inside of ****** (155mm) is divided into ten on the inspected material conveyance directional vision field center line of the line sensor camera 3, and it is transposing to 256 (8 bits) gradation data.
[0030] Drawing 4 shows the second operation gestalt of this invention, and a different place from the 1st operation gestalt is a point which replaced with the line light source 2 and has adopted the usual ultraviolet-rays light source 2A, and can expect the first operation gestalt and the operation effect of an abbreviation EQC. That is, the illuminance of the scanning direction S of the line sensor camera 3 does

not have nonuniformity within the camera visual field 4 as shown in drawing 4 (c). Moreover, since the visual field of the conveyance direction T of the inspected material 1 of the line sensor camera 3 is narrow about the conveyance direction T of inspected material 1 as shown in drawing 4 The exposure range of this direction T can be narrow, and can end, and can raise an illuminance, and, moreover, light source 2A is only leaned slightly. Since it can do few to illuminance nonuniformity while being able to remove the regular-reflection light 5 easily from the line sensor camera visual field 4, the shading compensation of the scanning direction S of the line sensor camera 3 is unnecessary.
[0031] In drawing 4 (a), about the component which is common in the first operation gestalt, drawing 1 (a) and a same sign are attached and details explanation is omitted.
[0032]
[Effect of the Invention] As mentioned above, this invention arranges a line sensor camera so that it may become vertical to an inspected material front face, while the inspected material conveyance direction and the scanning direction cross at right angles. Since it is characterized by making the exposure light source incline at the angle at which it is parallel to the scanning direction of said camera, and regular-reflection light does not enter in said camera light-receiving side to an inspected material front face Illuminance nonuniformity on the front face of inspected material can be made small, and the illuminance within a camera visual field can be raised, and improvement in inspection precision can be aimed at, without requiring a shading compensation.

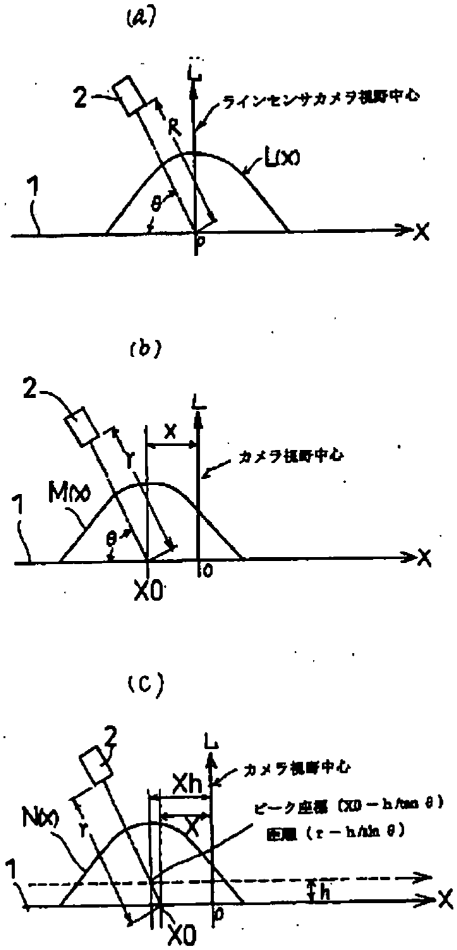
[Translation done.]

DRAWINGS

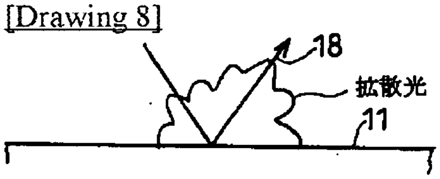
[Drawing 1]



[Drawing 2]

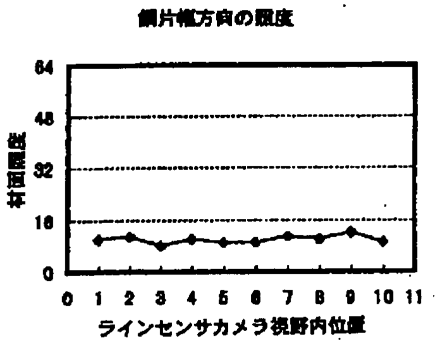


[Drawing 8]

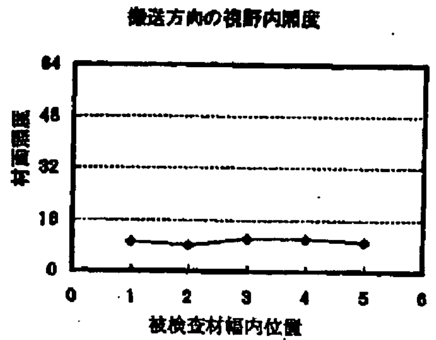


[Drawing 3]

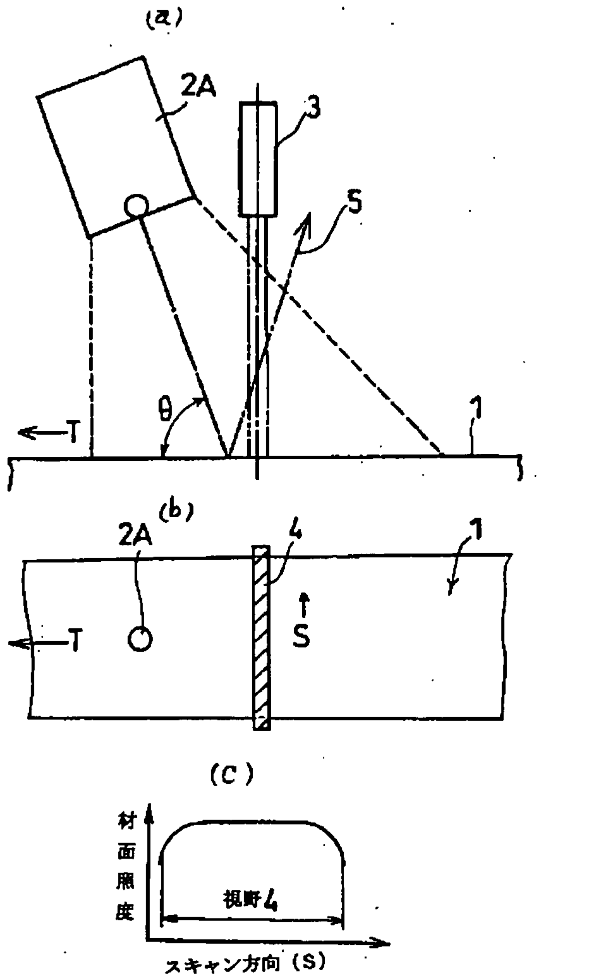
(a)


鋼片幅方向の照度
材面照度
64
48
32
16
0
0 1 2 3 4 5 6 7 8 9 10 11
ラインセンサカメラ視野内位置

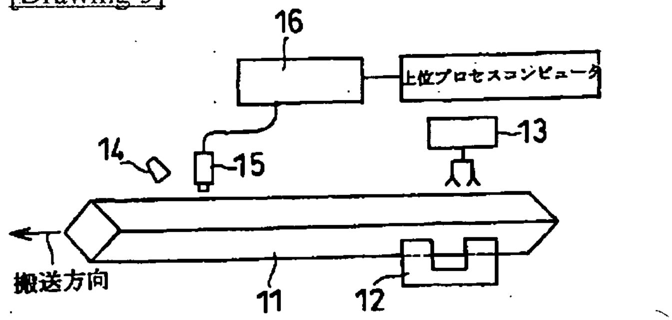
(b)


搬送方向の視野内照度
材面照度
64
48
32
16
0
0 1 2 3 4 5 6
被検査材幅内位置

[Drawing 4]



[Drawing 5]



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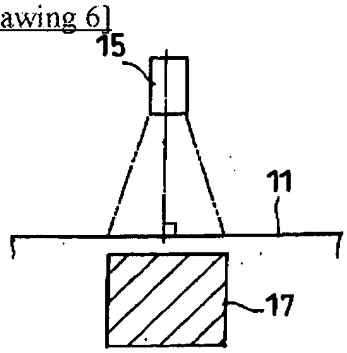
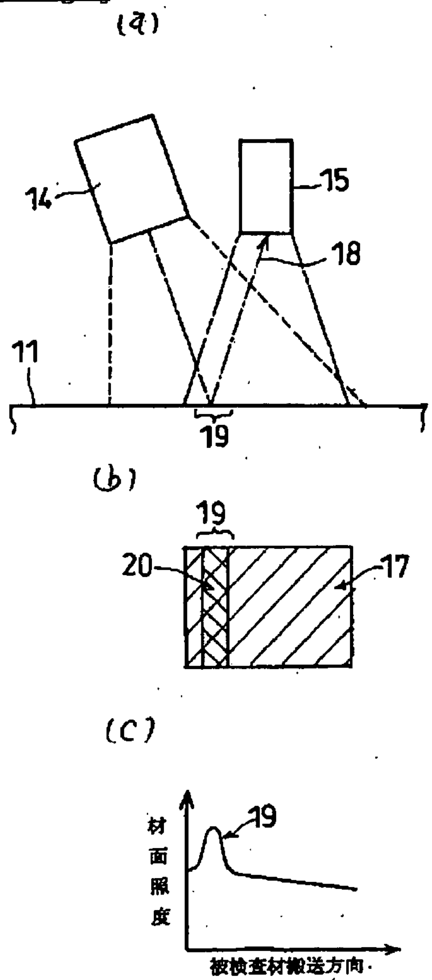
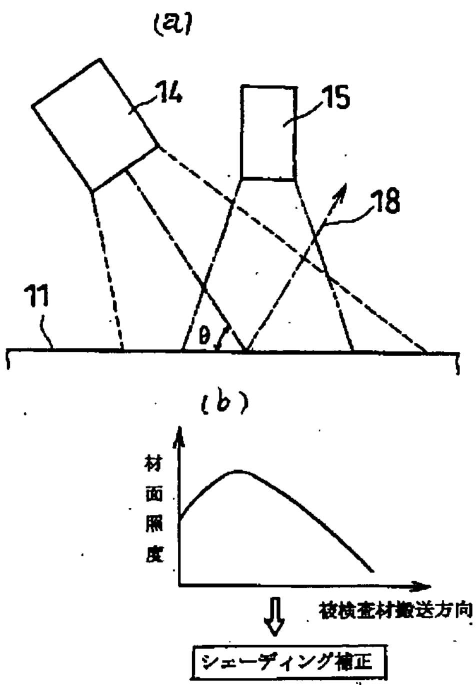


[Drawing 7]



[Drawing 9]



[Translation done.]

(19)日本国特許庁（JP）　(12) 公開特許公報（A）　(11)特許出願公開番号
特開2000－249688
(P2000－249688A)
(43)公開日　平成12年9月14日(2000.9.14)

(51)Int.Cl.⁷	識別記号	FI	テーマコード*(参考)
G01N 27/84		G01N 27/84	2G051
21/91		21/91	B 2G053

審査請求 未請求 請求項の数3 OL (全 7 頁)

(21)出願番号 特願平11－53277
(22)出願日 平成11年3月1日(1999.3.1)

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(54)【発明の名称】 湿式蛍光磁粉探傷法

(57)【要約】
【課題】 光源による正反射光をカメラ視野から外し易しくて、被検査材表面の照度ムラを小さくし、かつカメラ視野内の照度を上げ、シェーディング補正を要することなく検査精度の向上を図る。
【解決手段】 搬送中の被検査材1を磁化しながら表面に磁粉液を付着させ、照射光源2により欠陥部に発生する漏洩束部に凝集する磁粉を発光させ、ラインセンサカメラ3で撮影した画像データを処理することにより、被検査材1表面の結果を検出する湿式蛍光磁粉探傷法であって、前記カメラ3をそのスキャン方向Sが被検査材1の搬送方向Tと直交すると共に被検査材1表面に対して垂直となるように配し、前記光源2をカメラスキャン方向Sと平行でかつ被検査材1表面に対して前記カメラ3の受光面内に正反射光5が入らない角度θに傾斜させる。